The Temperature and Relative Humidity Control in Cushing Library

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ABSTRACT

Cushing Library located on TAMU campus is a special building, which needs precise temperature and relative humidity control, because it stores a number of rare collections and memorial books. There are five air-handling units (AHUs) serving the building. This paper will concentrate the unit, which serves the book stacks. This AHU is a multiple zone, constant air volume (MZCAV) system, with reheat and direct digital control (DDC). It has a standard cooling coil, glycol cooling coil, steam humidifier, and heat recovery. The chilled water to the standard cooling coil is served by the chilled water loop on the campus. There is a glycol chiller for the glycol cooling coil for added dehumidification ability. Because of programming problems and hardware problems, the relative humidity was not controlling properly. In this paper, the new control program for temperature and relative humidity control is implemented and the energy savings from the new control program is estimated. The temperature and relative humidity are now under control.

Table 1. The air handling system performance responsible for the current “standard museum environment” of around 72°F and 50% ± 5% relative

Part/Equipment Name	Performance Data	
Fan		
Fan CFM	12,500	
Total Static (inWG)	6.0	
Motor HP	25.0	
Standard Cooling Coil		
EDB / EWB (°F)	72.4 / 62.1	
LDB / LWB (°F)	50.5 / 50.2	
Total / Sens MBTU/H	424.3/ 296.9	
GPM	76.0	
EWT /LWT (°F)	45.0 / 56.2	
20% Glycol coil		
EDB / EWB (°F)	50.5 / 50.3	
LDB / LWB (°F)	42.8 /42.6	
Total / Sens MBTU/H	227.3 / 104.0	
GPM	60.0	
EWT /LWT (°F)	38.0 / 45.7	
Heat Pipes (recovery)	Precool Section	Reheat Section
EDB / EWB (°F)	81.0 / 65.2	42.2 / 41.2
LDB / LWB (°F)	63.9 / 59.2	59.3 / 49.4
Precool/Reheat (°F)	17.1	17.1
Heat Trans MBTU/H	235.1	235.1
Humidifier		
LBS/H	173.0	
Max KW	124.0	
Preheat Coil		
Air CFM	3,200	
EAT / LAT (°F)	44 / 104	
EWT / LWT (°F)	180 / 160	
GPM	26.0	
MIN MBTU/H	267	
Reheat Coil (TYP of 4)	Average	
Air CFM	3,700	
EAT / LAT (°F)	44 / 104	
EWT / LWT (°F)	180 / 160	
GPM	24.0	
MIN MBTU/H	236	
Glycol Chiller		
Total Tons	21.0	
Max KW	29	
GPM	60	
EWT /LWT (°F)	46 / 38	

GENERAL INTRODUCTION

The Cushing Library is a 3-story building with a basement. The total floor area is about 36,100 ft^2. The west part of the building is mainly office space, conference rooms and reading areas. The east part of the building contains book stacks with a total area of 10,500 ft^2. This library is a special building, because it stores a number of collections and memorial books, such as historical drawings, paintings and books. Therefore the book stacks need not only precise temperature control but also exacting relative humidity controls.

The physical, or more accurately mechanical, properties of cultural materials have been largely humidity (RH). Fluctuations of RH greater than ± 5% are considered responsible for the cracking of wood furniture and the flaking of panel and canvas supported paintings. While RH related damage is clearly established, temperature changes (independent of RH) are a subtler source of considerable damages. The real problem is that low temperature severely embrittles materials such as paints. Rapid change or excessive fluctuation of temperature or RH is another cause of damage.

Before July 2000, the relative humidity of the stacks was not controlling and the humidity alarm has been on for some time. Most of the time the humidity alarm was on, because the relative humidity was too low, around 35%.

AIR HANDLING SYSTEM

The air-handling unit (AHU), serving the book stacks located on the east part of the building from the basement to the 3rd floor, is a multiple zone, constant air volume (MZCAV) system, with reheat and direct digital control (DDC). Figure 1 demonstrates the air handling system for the book stacks. The system employs a preheat coil, heat recovery, standard cooling coil, glycol cooling coil, steam humidifier, and zone reheat. The chilled water to the standard cooling coil and hot water to preheat and reheat coils are served by the chilled water and hot water loops on the campus. There is a glycol chiller outside of the building for the glycol-cooling coil for added dehumidification ability. The AHU is equipped with heat pipes as a heat recovery system. There is a bypass on the reheat section of the heat pipes. The bypass damper (normally open) is interlocked with heat pipes damper (normally closed). When the stacks need reheat, the bypass damper is closed before zone reheats on. Otherwise, the bypass damper will be open. An electrical steam humidifier generates steam for humidification.

Table 1 demonstrates equipment performance data. The design airflow rate of the AHU is 12,500 CFM. The air temperature can be reduced from 72.4 °F to 50.5 °F by the standard cooling coil. The glycol coil has a capacity to treat air from 50.5 °F to 42 °F for further dehumidification. The heat pipes have a max heat transfer of 235.1 MBTU/H from precool section to reheat section. It results in the max energy saving of 235.1 MBTUH on both reheat and cooling energy usages. The humidifier has a capacity of 173 lbs/hr. Preheat and each zone reheat has a min heating capacity of 267 MBTU/H and 236 MBTU/H respectively.

OLD CONTROL SCHEME AND ISSUES

Zone temperature and relative humidity were controlled at 65°F and 50% ±5%.

The glycol coil served by the glycol chiller is designed for added dehumidification. But according to the chiller control demonstrated in Figure 2, the glycol chiller was on all the time while the AHU was on. It cost unnecessary electricity consumption and hot water consumption, when the standard cooling coil can handle stack temperature and relative humidity by itself.

Figure 3 demonstrates chilled water valve, glycol valve and heat pipes bypass damper controls. The chilled water control valve and glycol control valve were controlled by two control loops separately. The

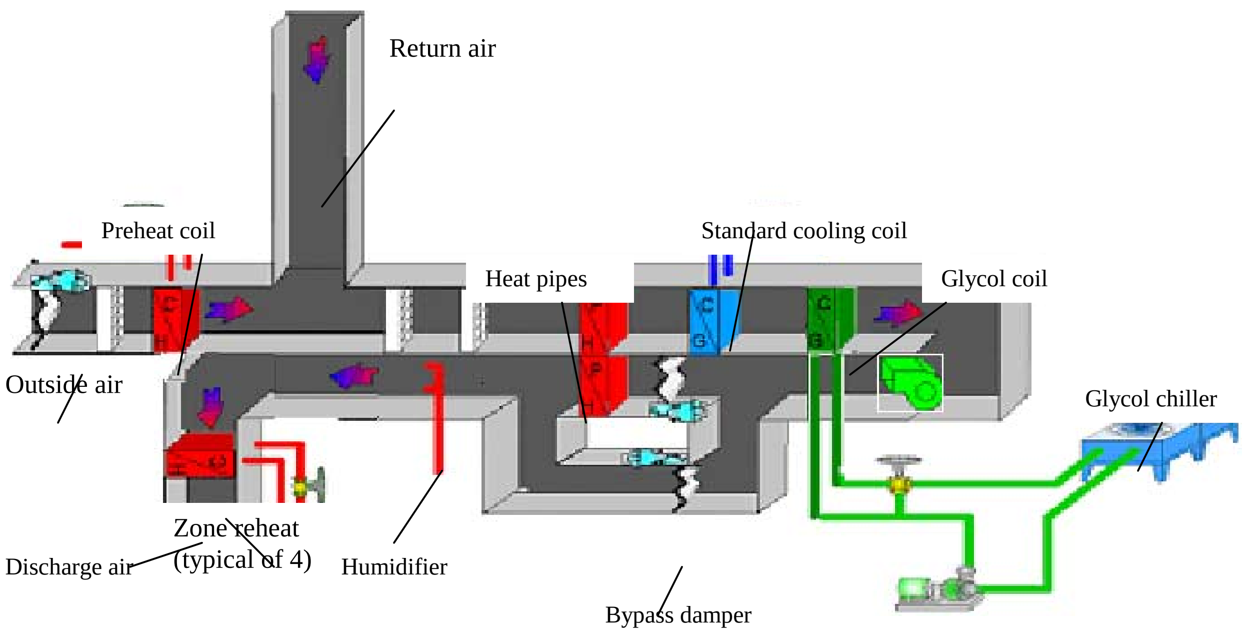

Figure 1. Air handling system diagram

heat pipes bypass damper was controlled by three control loops. This resulted in the zone temperature and relative humidity not controlling properly. For instance, the glycol valve was controlled to maintain max RH at its setpoint of 55% and temperature after the glycol coil at its setpoint of 38 °F. When max zone RH was lower than 55% and temperature after the glycol coil is higher than 38°F, the RH control loop would close the glycol valve to reduce dehumidification, but the temperature control loop would open the valve to reduce the temperature. This caused the relative humidity to fluctuate. Also the 38°F air temperature setpoint after the glycol coil, point (a) in Figure 6, is the main reason for causing

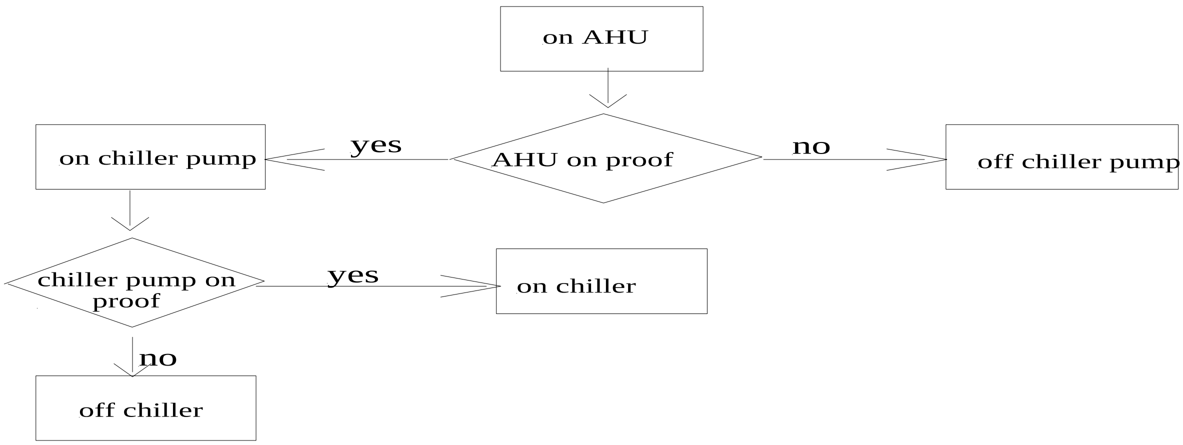

Figure 2. Chiller on/off control diagram (old)

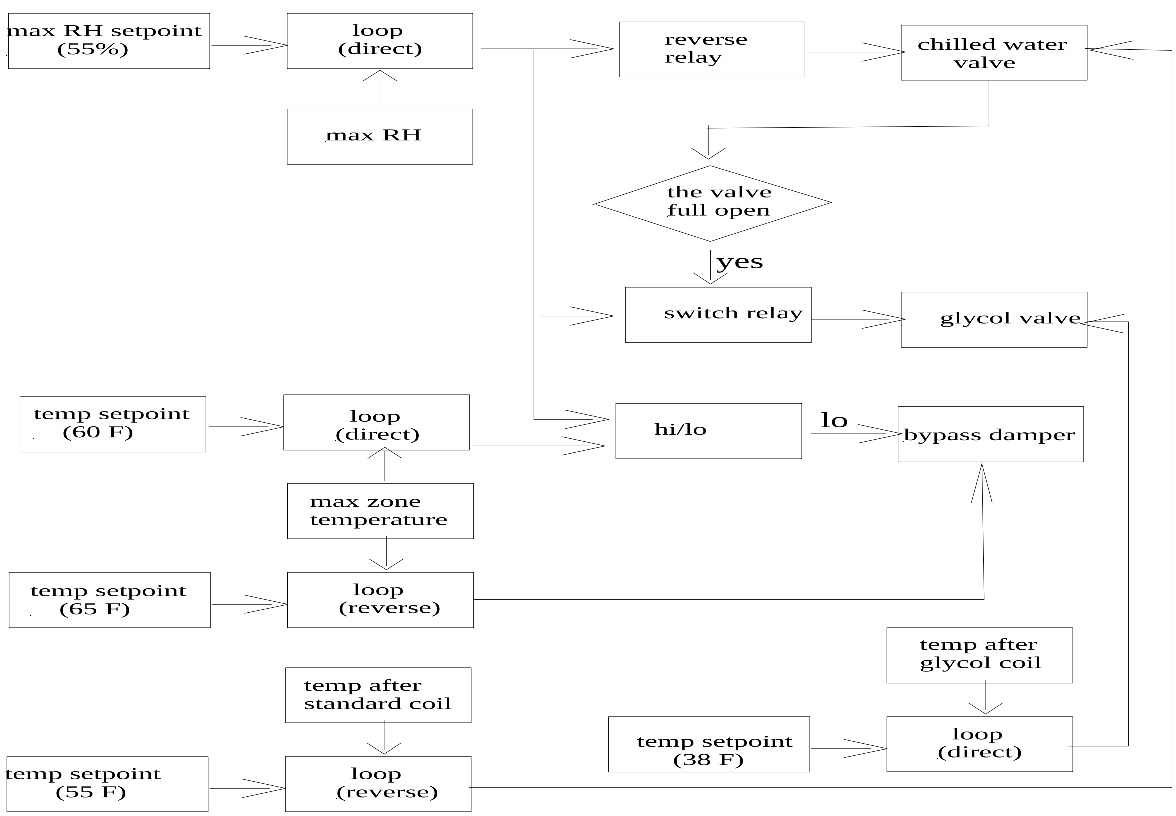

Figure 3. Chiller water valve, glycol valve and heat pipes bypass damper control diagram (old)

the relative humidity too low. For example, when zone temperature is 65 °F at its setpoint and humidifier is off when out side air relative humidity is higher than 75%, seeing Figure 4, the zone RH would be around 35%, point (b) shown in Figure 6. In this situation, the RH alarm would be on. When the out side air relative humidity was lower than 75%, the humidifier was commanded to be on to maintain RH at its setpoint. But if the temperature after glycol is 48°F, point (d) instead of 38 °F, the humidifier was not commanded to be on. For the chilled water valve, it is very hard or impossible to maintain 55 °F after standard coil and 55% of max zone RH under the control of two control loops. For the heat pipes bypass damper, the direct control loop could not maintain zone temperature at its setpoint, because the bypass damper is normally open. The temperature control loop should be direct control for the bypass damper to maintain zone temperature at its setpoint.

Figure 4 demonstrates the humidifier control. There are five humidity sensors located in room 005, 115, 207, 208, and 305. The humidifier is controlled to maintain minimum zone relative humidity at its setpoint of 45%, when outside air RH is lower than 75%. The humidifier is off, when outside air RH is higher than 75%. When outside air RH is between 70% and 75%, the humidifier is controlled by the control loop output weighted with linear outside air relative humidity as below.

Humidifier = control loop output *(75 – RHoa) / 5

Here RHoa is outside air relative humidity.

Figure 5 demonstrates zone reheat valve control. The terminal equipment controllers (TEC) control reheat valves to maintain zone temperature at its setpoint of 65 °F. This setpoint is as same as the setpoint of the heat pipes bypass damper control. To save heating and cooling energies, the bypass damper

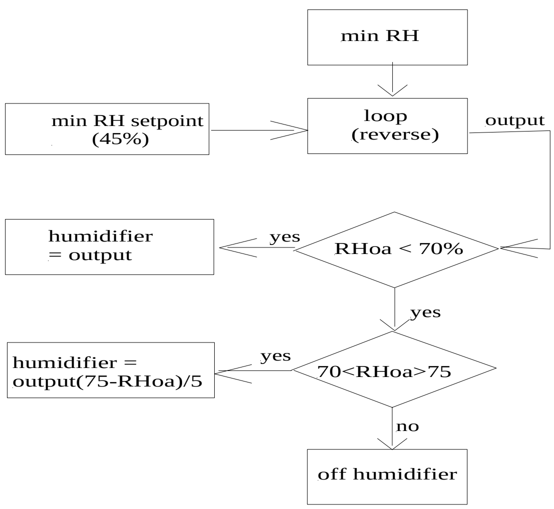

Figure 4.   Humidifier control diagram (old)

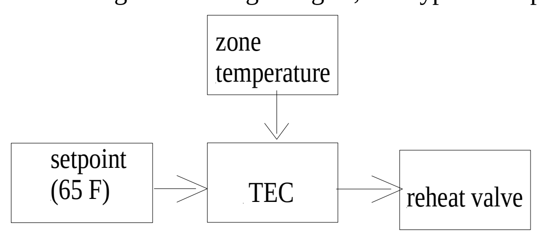

Figure 5. Zone reheat valve control diagram (old)

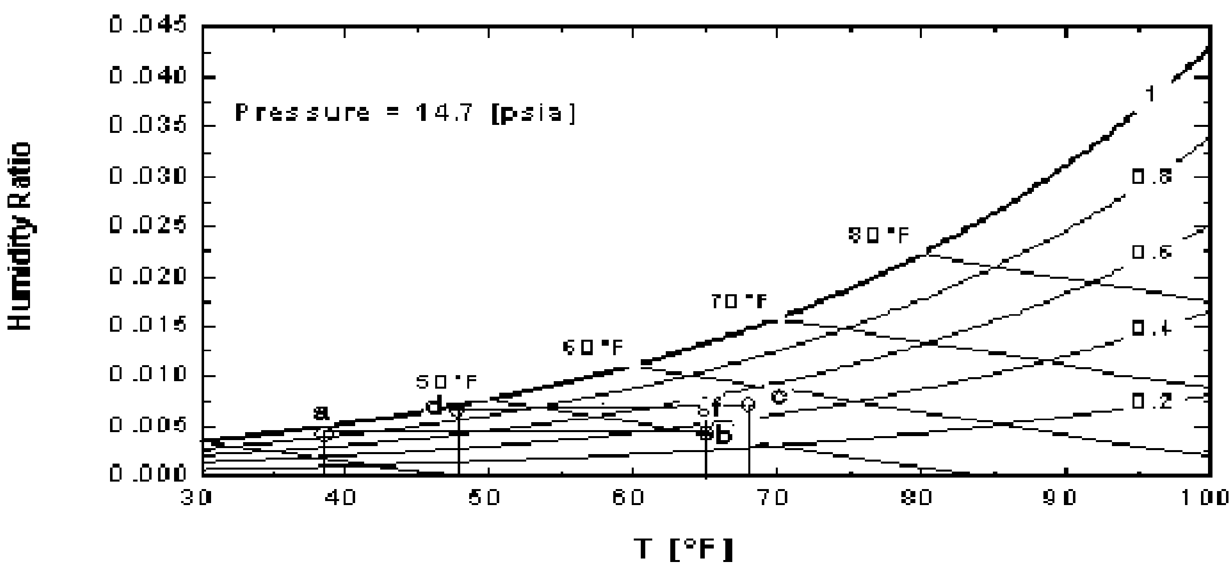

Figure 6.   Zone temperature and RH control point

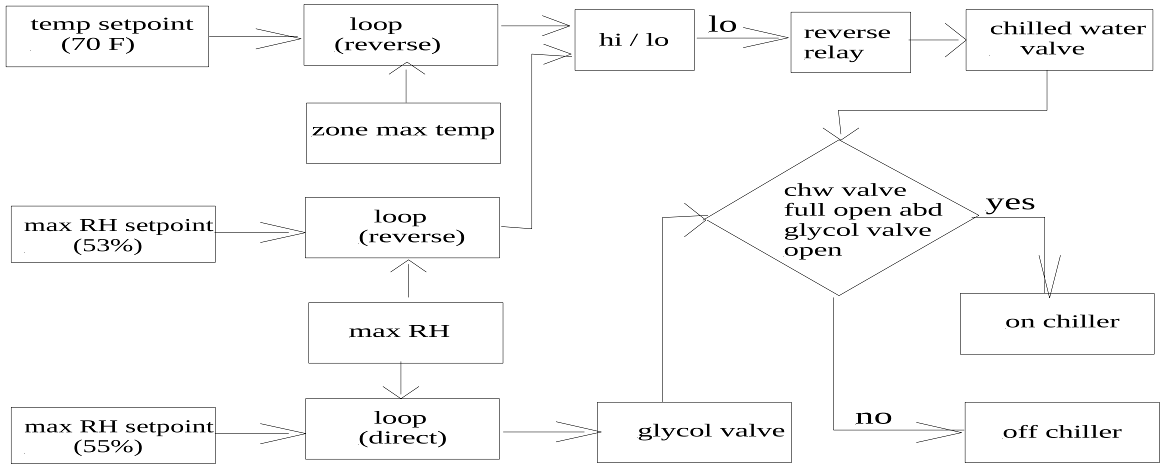

Figure 7. Chiller water valve, glycol valve and chiller control diagram (new)

should be closed earlier than the zone reheat valve is open.

To say the least, the existing control program was not working.

NEW CONTROL SCHEME AND OPERATION

For proper room temperature, RH requirements, and energy management, the zone temperature setpoint was increased from 65°F to 68°F for heating and 70 °F for coiling. The relative humidity setpoint is 50% ±5%, the same as before. The new setpoints of 68°F and 50% ±5%, point (c) in Figure 6, require discharge air temperature setpoint of 48°F for the glycol coil, instead of 38°F. It reduces electricity consumption of both the glycol chiller and the electrical humidifier.

Figure 7 demonstrates the new control scheme for the chilled water valve, glycol valve and chiller. The plant chilled water control valve is modulated to maintain zone-cooling temperature at its setpoint of 70°F and max zone RH at 53% of its setpoint. The humidity setpoint for chilled water valve is 2% lower than the setpoint of 55% for the glycol valve, so that the glycol valve will be open for further dehumidification, after the plant chilled water valve is fully open. The glycol chiller will cycle on, as it is needed.

Figure 8 demonstrates the new control scheme of heat pipes bypass damper and zone reheat valve for zone reheat only. The temperature setpoint for heat pipes bypass damper is 69°F, which is 1°F higher than the setpoint of 68°F for the zone reheat valve, so that the reheat valve will be open for further reheat, after the heat pipes bypass damper is fully closed.

The relative new control schemes were implemented during commissioning by the Continuous Commissioning (CC[SM]) group at the Energy Systems Laboratory (ESL), Texas A&M University (TAMU). The CC[SM] process was conducted from January to March 2001, under direction of and in cooperation with the TAMU Physical Plant Energy Office. The performance of the new control program for temperature and humidity control in Cushing Library was observed over a one-year and a half period. It is functioning well. The temperature and relative humidity of the book stacks are under control and the RH alarm has remained off. Under the old control program, the glycol chiller was on all year around. But with the new control program, the glycol chiller was on only when outside air was hot and humid, from July to September. During the rest of the year, the chiller was off. The estimated electricity saving for the glycol chiller is $12,900 annually.

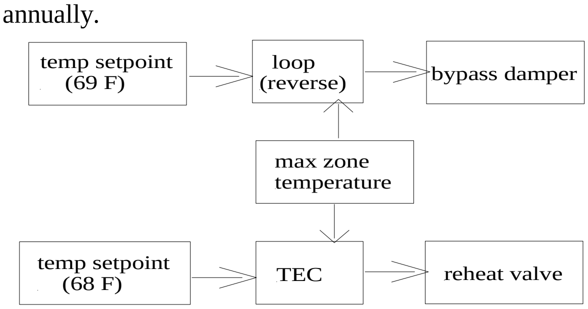

Figure 8. heat pipes bypass damper and reheat valve control diagram (new)

CONCLUSION

The air handling system for the collections and memorial book stacks in Cushing Library was studied and the control schemes are optimized in this paper. The new control schemes for the temperature and relative humidity control was generated and implemented. Over a year and a half period the new control schemes are functioning well. The temperature and relative humidity of the book stacks were improved and annual electricity saving of $12,900 for the glycol chiller only is estimated.

ACKNOWLEDGMENT

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